Mass spectrum of heavy meson states with $Q\bar{q}$ and $q\bar{Q}$ wave function in non-relativistic quark model

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Introduction

The greatest task of the phenomenology is to explain the mass spectrum and decays of hadrons under a unified model. There is a wealth of experimental data in hadron spectroscopy that emerges from a number of experimental facilities such as BES, E835, CLEO, BaBar, Belle, CDF, DO, NA60 etc. This offers a great challenge to the phenomenology to device a theoretical framework under one unified model.

The non-relativistic quark models (NRQM) are a class of phenomenological models developed to explain the hadron interactions. They give the most complete description of hadron properties and are the most successful phenomenological models of hadron structure [1-2]. In studying mesons in the frame work of NRQM, one usually assumes that the $q\bar{q}$ wave function is a solution of a non relativistic Schrödinger equation.

The Hamiltonian of these quark models usually contains three main ingredients: the kinetic energy, the confinement potential and a hyperfine interaction term which has often been taken as an effective one- gluon- exchange potential (OGEP)[3]. In literature there are various forms of potentials that give reasonable accounts of the $c\bar{c}$ and $b\bar{b}$ spectra: the QCD motivated potential given by Buchmuller and Tye [4], a power law potential [5-6], a logarithmic potential [7], a Coulomb-plus-linear potential (Cornell potential)[8]. The OGEP in our model is obtained from non relativistic reduction of the Fermi-Breit interaction.

In heavy meson spectroscopy non relativistic models are found to be more suitable in studying the mass spectra, predicting the higher orbital states and other properties like leptonic and two photon decays. The Hamiltonian employed in our model is given by [9],

$$H = K + V_{CONF}(\vec{r}) + V_{OGEP}(\vec{r})$$

Results and discussions

Using the non relativisitc quark model we have calculated the masses of heavy $Q\bar{q}$ and $q\bar{Q}$ where q and Q are light and heavy quarks respectively. We have studied the mass spectra in the case of S, P and D wave singlet and triplet heavy mesons which include charmed, charmed strange, bottom and bottom strange mesons.

In our calculation we have expressed the product of quark-antiquark oscillator wave functions in terms of oscillator wave functions corresponding to the relative and centre-of-mass coordinates (CM). The oscillator quantum number for the CM wave functions is restricted to N_{cm}= 0. The Hilbert space of relative wave functions is truncated at radial quantum number n_{max} = 4. The Hamiltonian matrix is constructed for each meson separately in the basis states of $\left| N_{CM} = 0, L_{CM} = 0;\ {}^{2S+1}L_J \right\rangle$ and is diagonalised. The masses of the singlet and triplet heavy mesons after diagonalisation in harmonic oscillator basis with n_{max}= 4 are listed in table 1.

Conclusions

The phenomenological non-relativistic quark model (NRQM) has been employed to obtain the masses of various heavy states. The Hamiltonian used in the investigation has kinetic energy, confinement potential and one-gluon-exchange potential (OGEP). The total energy or the mass of the meson is obtained by calculating the energy eigen values of the Hamiltonian in the harmonic oscillator basis. An overall agreement is obtained with the experimental masses [10].

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Table 1 Masses of heavy mesons (MeV)

$^{2S+1}L_J$	Meson	Exp. Mass[10]	Calculated mass
$^1S_0$	D	1869.62±0.2	1860.65
	D_s	1968.49±0.34	1946.14
	B	5279.15±0.31	5276.23
	B_s	5366.3±0.6	5356.78
$^3S_1$	D^*(2010)	2010.27±0.17	2002.76
	D_s^*	2112.3±0.5	2087.96
	B^*	5325.1±0.5	5295.27
	B_s^*	5412.8±1.3	5424.94
$^3P_0$	D_{S0}^*(2317)	2317.8±0.6	2310.76
$^3P_1$	D_1(2420)	2422.3±1.3	2417.30
	D_{S1}(2536)	2535.35 ± 0.34 ± 0.5	2529.42
	B_1(5721)	5720.7 ± 2.7	5710.67
	$B_{S1}(5830)^0$	5829.4 ± 0.7	5811.34
$^3P_2$	$D_2^*(2460)^0$	2461.1±1.6	2463.12
	D_{S2}(2573)	2572.6±0.9	2567.53
	$B_2^*(5747)^0$	5746.9 ± 2.9	5735.54
	$B_{S2}^*(5840)^0$	5839.7± 0.6	5821.26
$^3D_1$	$D^*(2007)^0$	2006.97 ± 0.19	2004.72
	B^*	5325.1 ± 0.5	5306.98